Copyright © 1980 Ohio Acad. Sci. 0030-0950/80/0004-0150/$2.00/0

EFFECTS OF HUNTING ON HUNTER EFFORT AND WHITE-TAILED DEER BEHAVIOR[1]

GERALD A. GRAU[2], Ohio Cooperative Wildlife Research Unit, Ohio State University, Columbus, OH 43210
BRENDA L. GRAU[3], Department of Zoology, Ohio State University, Columbus, OH 43210

Abstract. Controlled hunts were held on the NASA Plum Brook Station near Sandusky, Ohio, during the winters of 1975–76 and 1976–77 to reduce the white-tailed deer (*Odocoileus virginianus*) population. Primary and alternate hunters were chosen by public drawing, and 57% (n = 1423) of the 2497 hunters were interviewed during the hunt to determine hunter effort and success. White-tailed deer flight reaction was measured before and during the controlled hunts. As the hunting seasons progressed, the hunters put in more effort and had less success, and deer showed an increased avoidance behavior towards humans. The differences between results of morning and afternoon hunts indicated changes in deer behavior played a large role in the kill-rate decline during the season. Wounding rates were not correlated with the increasing difficulty of the hunt.

OHIO J. SCI. 80(4): 150, 1980

Large populations of cervids often develop on areas where hunting is incompatible with the current activities and is not permitted (Leopold 1963). Such a situation developed on the National Aeronautics and Space Administration's (NASA) Plum Brook Station near Sandusky, Ohio. This 2,176 ha station is enclosed by a 2.44 m cyclone fence that prevents emigration of white-tailed deer. NASA restricted all hunting when it obtained the site in 1956 and by the mid-1960's the white-tailed deer were a problem (Harder and Peterle 1974). More than 3,900 deer were removed by trapping and professional hunting between 1966 and 1974 (Andrews *et al* 1977), but the population continued to increase; by January 1975 the population was estimated at 2,499 deer, or 115/km^2 (298/mi^2) (Rice and Harder 1977).

In an effort to reduce this population, public hunts were held on 22 and 29 November, 13 and 20 December 1975, 10, 17, 24, and 31 January, and 7 February 1976, 6, 13, 20, and 27 November, 11 and 18 December 1976, and 8 and 15 January 1977. Hunters were chosen by public drawing and designated either as primary or alternate. Each primary hunter was assigned a specific area ($\bar{X}$ = 24 ha) to hunt on foot. They were allowed to hunt all of their assigned area, but were not allowed to leave the area, even to follow wounded animals. Two hunts were conducted each day and hunters were required to use shotguns and slugs. The primary hunters were transported to their assigned areas at specified times for the morning and afternoon hunts. Some alternate hunters replaced primary hunters after the latter brought their deer to the check station. A few alternates were guided through areas containing structures or equipment. These hunters were told which deer to shoot and were allowed to shoot from the road. Deer also were removed by trapping and by professional hunting for scientific collections during the winters of 1975–76 and 1976–77.

The objective of this study was to document changes in hunter effort and deer response to human activity during the public hunts. Previous studies indicated that an increase in hunter effort (Holsworth 1973, Van Etten *et al* 1965)

[1]Manuscript received 19 April 1979 and in revised form January 1980 (#79-26).

[2]Present address: Fish and Wildlife Service (PCR), U.S. Department of the Interior, Washington, D. C. 20240.

[3]Present address: 7513 Citadel Dr., College Park, MD 20740.

and an increase in flight distance (Behrend and Lubeck 1968) could be expected. Flight distance is the distance to which a person can approach a wild animal without causing it to flee (Altmann 1958, Hediger 1968). The deer on Plum Brook Station were disturbed by professional hunts for scientific collection in 6 of the 8 winters preceeding the first public hunt. These 6 hunts, usually on 2 consecutive days, were conducted in vehicles and resulted in 666 deer killed with shotgun slugs. The trapping and removal efforts also caused some disturbances prior to the public hunts. In spite of these disturbances, deer on Plum Brook Station were relatively easy to observe prior to the public hunts.

METHODS

All hunters were required to report to the check station at the end of each hunt. Hunters in 7 (22 and 29 November 1975; 10, 17, 24 and 31 January; 7 February 1976) of the 9 hunts in 1975–76 and 3 (6, 13, and 27 November 1976) of the 8 hunts in 1976–77 were interviewed to determine the amount of effort needed to kill each deer. Each hunter was asked to supply information on the number of shots fired, number of deer he shot at, estimated distance of the killing or missed shots (in yards, the system all hunters understood), time of the kill, sex and age of the deer killed, number wounded, number of years they had hunted deer, and whether or not they had ever received firearms training. No attempts were made to check the accuracy of the interview data, but the guides reported that those hunters who fired a large number of shots tended to under report this number. Thus our data are conservative on items that tend to be under reported. The estimated amount of time in the field was most accurate for the primary hunters, so only these hunters were used in the analysis of effort.

Our figures on the deer population of Plum Brook Station were based on the census (298 per mi^2 in January 1975) by Rice and Harder (1977), the population model developed for this population (Harder, personal communication), and U.S. Fish and Wildlife Service records (Andrews *et al* 1977) on the number of deer removed from the Station (2895 deer removed from 1975 through 1977). We estimate that 344 deer/mi^2 were available at the start of the 1975–1976 hunt.

The flight reaction of white-tailed deer was documented on 21, 22, 23 October; 8 December 1975; 28 October; 5, 26 November; and 4, 10 December 1976. Deer feeding at the edge of road were approached in a vehicle. When these deer fled, the vehicle was stopped and the distance to the site at which the deer had been standing was paced. Paced distances were consistent because of the level terrain (road) and because the number of paces per 100 feet was measured 4 times prior to each day's recording of flight reaction. To minimize variation due to factors other than disturbance by humans (Altmann 1958, Kucera 1976, Walther 1969), data were collected only in the late afternoon from single adult females standing or grazing along the roadside (not from deer moving across the road) and fully aware of our approach. The responses of deer meeting these criteria were recorded as withdrawal distance for those deer walking or trotting away as soon as they saw us, or direct flight distance for deer slowly galloping away after watching our approach (Walther 1969). We also recorded vocalizations, tail postures, and whether or not deer remained in the brush close to the area where the flight began.

RESULTS

During the 2 public hunts, 2494 hunters participated and killed 1,330 deer (53.3% success). These hunts accounted for 54% of the deer removed by all the methods used in reducing the deer population from 2,886 in November 1975 to 640 in the fall of 1977 (Andrews *et al* 1977).

We interviewed 1423 (57%) of the hunters participating in the 2 public hunts. Of the primary and alternate hunters interviewed, 31% had received some form of firearms training. Only 7% of the hunters indicated that they were hunting deer for the first time, but 50% of those interviewed had hunted deer in 7 or fewer years previously. One individual reported that he had hunted deer for 53 years. We determined that 85.8% of the interviewed hunters fired at least 1 shot, and 4,240 shots were fired at 2,246 deer, of which 817 were killed ($\bar{X}=5.19$ shots/kill, $\bar{X}=1.89$ shots/deer shot at). Successful hunters averaged 3.32 shots/kill, and their average estimate of the killing distance was 47 yd. The mean kill rate was 0.208 deer killed per hunter-hour in the field. The hunters we interviewed reported wounding 161 deer (0.197 wounded/deer killed, 0.11 wounded/hunter in the field (or 0.07 wounded/deer shot at versus 0.36 killed/deer shot at)). Surveys at the end of the 2 hunting seasons revealed that 232 deer died from hunting wounds but were not recovered by hunters (0.17 crippled/deer killed, 0.09 crippled/hunter in the field) (Andrews *et al* 1977).

Because all the primary hunters were on foot, were without a guide in unfamiliar terrain, and were in and out of the field at known times, data from inter-

views of these hunters are used to show trends of season length on hunter success and effort. Data for the morning and afternoon hunts are presented separately because of some obvious differences in the results. Along with a decline in hunter success (fig. 1a), increased effort was needed to kill deer in each subsequent hunt. There appeared to be less opportunity to make a kill as shown by the decline in the portion of hunters getting at least one shot (fig. 1b) in the morning hunts but not in the afternoon hunts. Successful hunters in the morning generally required more time as the season progressed, but the time required did not differ significantly, as shown by the large standard errors (table 1). The portion of the morning kill that occurred in the first 1.5 h declined in subsequent hunts, whereas the same portion remained somewhat stable in the afternoon (fig. 1c).

The deer also may have been more difficult targets in the later hunts. Successful hunters tended to fire more shots in the morning hunts as the season progressed (table 1), and the estimated killing distance increased more in the morning than in the afternoon (fig. 2). Apparently, these hunters fired additional times at the deer they eventually killed because the number of deer escaping from successful hunters did not increase (table 1). The portion of the deer population that was shot at by primary hunters but escaped increased after the first few hunts and then remained relatively stable (fig. 1d). The increased target difficulty did not, however, increase the reports of wounding deer (fig. 1e) as the season progressed. The high wounding rates in both the morning and afternoon of the 8th hunt in 1975–76 indicate that some factor other than season length was

TABLE 1

Data from interviews of primary hunters who killed deer during public hunts on Plum Brook Station in 1975–76 and 1976–77.

Date	Hunt #	No. Shots ($\bar{X}\pm$SE)	No. Escapes	Min. in field ($\bar{X}\pm$SE)
MORNING HUNTERS				
1975–76 hunting season				
22 Nov 75	1	3.1±0.6	0.5	89±16.4
29 Nov 75	2	3.2±0.7	0.5	112±19.0
10 Jan 76	5	3.3±0.7	0.3	109±21.8
17 Jan 76	6	3.8±1.4	0.6	112±24.2
24 Jan 76	7	4.4±2.5	1.0	120±27.9
31 Jan 76	8	3.0±1.1	0.4	138±28.6
7 Feb 76	9	4.5±1.8	0.5	125±33.0
1976–77 hunting season				
6 Nov 76	1	3.6±0.7	0.8	119±15.2
13 Nov 76	2	3.9±1.0	0.8	130±18.8
27 Nov 77	4	4.5±1.3	1.2	143±20.2
AFTERNOON HUNTERS				
1975–76 hunting season				
22 Nov 75	1	2.4±0.4	0.3	102±19.2
29 Nov 75	2	3.1±0.8	0.7	117±16.0
10 Jan 76	5	3.1±0.8	0.6	98±21.2
17 Jan 76	6	3.8±1.2	0.8	87±21.8
24 Jan 76	7	3.3±1.1	0.8	118±26.4
31 Jan 76	8	3.2±0.9	0.7	103±23.2
7 Feb 76	9	3.0±0.7	1.0	96±28.6
1976–77 hunting season				
6 Nov 76	1	3.1±0.6	0.5	100±16.2
13 Nov 76	2	2.7±0.6	0.4	98±15.2
27 Nov 76	4	2.5±0.6	0.4	106±23.0

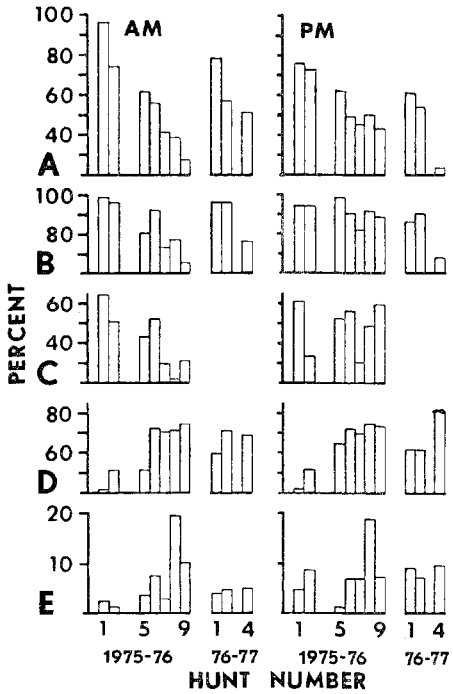

FIGURE 1. Comparison of primary hunters in morning and afternoon hunts in 1975–76 and 1976–77 on NASA Plum Brook Station. A. Percentage of the interviewed hunters that killed deer, B. Percentage of the interviewed hunters that fired at least one shot, C. Percentage of the kill that occurred within the first 90 min of each hunt, D. Percentage of the white-tailed deer that were shot at but escaped, and E. Percentage of the white-tailed deer that were shot at and wounded but not recovered by that hunter.

affecting these rates. Our weather records do not show any unusual conditions on that date.

As the season progressed, the reduced deer population undoubtedly lowered each hunter's prospect for bagging a deer. Any change in the deer's behavioral response to the hunters due to the disturbance of previous hunts could also affect hunter success. The amount of effort, as measured by man-minutes in the field, required for each kill generally increased as the season progressed and was highly correlated with the estimated number of deer available, number of previous hunts, number of deer wounded in previous hunts, number that escaped

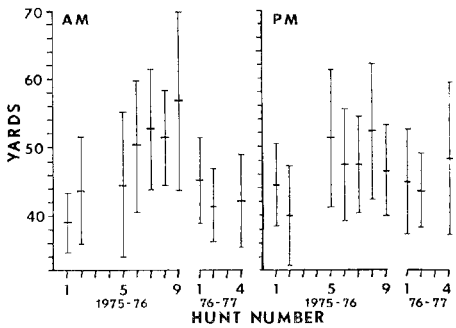

FIGURE 2. The estimated distance ($\bar{X} \pm 2SE$) of the kills made by primary hunters at NASA Plum Brook Station.

in previous hunts, and number of shots fired previously ($r = -0.95$, 0.95, 0.97, 0.96, and 0.96, respectively). Interpretation of the correlation data is difficult because, by definition, the independent variables must either increase or decrease with each subsequent hunt.

The regression equations for kill rate versus population size differed (fig. 3)

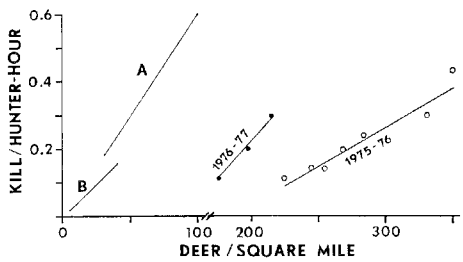

FIGURE 3. Kills per hunter-hour in the field in relation to deer availability for primary hunters in 1975–76 ○=daily $\bar{X}$, ($C[t] = -0.449 + 0.00241N[t]$) and 1976–77 ●=daily $\bar{X}$, ($C[t] = -0.664 + 0.00445N[t]$) at NASA Plum Brook Station as compared to data from (A) Holsworth (1973) ($C[t] = 0.006N[t]$) and (B) Van Etten *et al* (1965) ($C[t] = 0.00399N[t]$). C[t] is the kill rate at time t and N[t] is the population density at time t (Van Etten *et al* 1965).

from the equations reported in previous studies (Holsworth 1973, Van Etten *et al* 1965). The 1976–77 hunting season on Plum Brook Station showed a decline in the kill rate similar to the previous studies, but the 1975–76 season had a shallower slope or slower decline in the kill rate. The kill rate decline was faster

for the morning hunts than for the afternoon hunts in 1975–76 (fig. 4). The dense population on the station did not result in the high kill rates that could be projected from the previous studies. Instead, the slopes were shifted to the right and the intercepts became negative rather than zero.

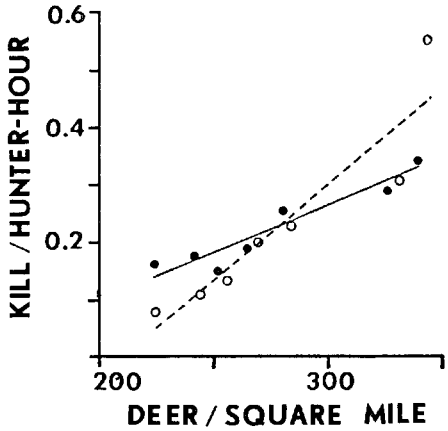

FIGURE 4. The 1975–76 kills per hunter-hour in the field in relation to deer availability for primary hunters in morning ○=daily $\bar{X}$; (- - - - =regression slope of 0.0036) and afternoon hunts ●=daily $\bar{X}$; (———=regression slope of 0.00164).

The flight response of deer changed as hunting progressed on Plum Brook Station. The direct flight distances from vehicles were highly variable both before and during the public hunt, and no significant changes were detected. The number of withdrawal reactions, however, was significantly greater ($\chi^2=8.07$, 1df, $P<0.005$) during the public hunt than before, and the withdrawal responses also were at significantly ($P<0.005$) greater distances than the flight reactions. These data on withdrawal were supported by our more subjective observations on the deer's reaction to humans. For example, deer in woody cover near the road remained in the area when vehicles drove by prior to the public hunt but not after the hunt. As the hunting season progressed, hunters complained more about not seeing deer or not being able to get within shooting range. Finally, the professionals making the monthly scientific collections after the public hunts were forced to switch from shotguns and slugs to weapons with accuracy at greater ranges to kill the number of deer required for the sample.

DISCUSSION

The 2 public hunting seasons on Plum Brook Station were a significant part of the white-tailed deer herd reduction program. These hunts accounted for over half the deer removed, and they provided a recreational opportunity for many hunters. Most hunters shot at or at least saw deer. The distribution of these hunters on the station allowed them to use their own hunting ability and provided them with a hunt undisturbed by other hunters.

The hunter success rate of 53% was much higher than the rates reported for other controlled hunts (Krefting and Erickson 1956, Krefting *et al* 1955, Roseberry *et al* 1969) and probably resulted from the extremely dense deer population on the station. The average kill rate (0.208 deer killed/hunter-hour) for the 1975–76 hunt at Plum Brook Station, however, was well below the average kill rate (0.34 deer killed/hunter-hour) reported by Holsworth (1973), even though the Plum Brook population was 3.5 times as dense. As reported in other studies (Holsworth 1973, Roseberry *et al* 1969, Van Etten *et al* 1965), the hunter success rate and kill rate declined as the season progressed. Apparently, the kill rate is not entirely dependent upon population density (fig. 3), and when used alone it is not adequate for population estimation as suggested by Holsworth (1973).

In addition to population density, other factors such as weather, habitat, hunting method, and behavior also could influence hunter success and kill rates. Our study was too limited to determine the effect of weather and habitat, and the hunters who participated were relatively evenly distributed over unfamiliar territory and had only a few hours to evaluate the area and hunt. Thus, the amount of time needed for each kill would be increased by this unfamiliarity with the area. Behrend and Lubeck (1968) showed that deer on unhunted areas allow humans to approach closer than do the deer

on areas where hunting was permitted. The deer on Plum Brook Station changed their total flight behavior in response to hunting by increasing the number of slow, inconspicuous avoidances at relatively long distances rather than by increasing the distance in the faster but more attention-attracting direct flight. In fact, the differences in kill rates, percent of hunters firing, percent of kill in the first 90 minutes, and kill distance between the morning and afternoon hunts as the hunting season progressed suggest the hypothesis that hunt success was affected by changes in deer behavior. Though behavior varies considerably over time and place, white-tailed deer theoretically should have been moving about during the morning hunts and resting during the early part of the afternoon hunts. Thus, the active deer in the morning would withdraw from approaching hunters by immediately leaving the area. Since the hunters were widely dispersed, the deer were not forced to enter another hunter's assigned area. It is possible that deer resting in the afternoon may have allowed the hunters to approach closer for 2 reasons. Resting individuals were probably not as "ready" to flee as they are during their more active period in the morning (Walther 1969), and a stronger stimulus would be necessary to elicit flight during these resting periods. Resting deer also may have tried to hide from approaching hunters by retaining their position until the last possible moment. In either case, resting individuals would allow hunters to approach closer than would active deer. Thus, deer avoidance behavior probably played a large role in determining hunting efficiency, and it must be considered if kill rates are used to estimate population density.

The accuracy of our wounding rate measurement was affected by at least 2 factors we did not measure. If the hunters did not report all the animals they wounded, our wounding rate figures would be low, but, in many instances, deer wounded by one hunter were killed by another hunter, which made our wounding rate (unrecovered deer) high. However, our wounding data probably reflected what was actually occurring, because they were similar to the crippling rates calculated from the dead deer survey at the end of the hunts and to the crippling rates reported by Losch and Samuel (1977). Our most interesting finding was that as the hunting became more difficult due to fewer deer available and a change in deer behavior, the wounding rate did not show an upward trend.

The results of the public hunt at Plum Brook Station showed the advantages of short hunting seasons over longer ones. The decline in hunter success as the season progressed increased the cost per kill for management and enforcement personnel and increased hunter complaints about the availability of deer. The longer hunts also made the deer more difficult to observe than did the shorter hunts prior to public hunting on the Station. The latter result supports the hypothesis that hunting is not incompatable with viewing (Behrend and Lubeck 1968), but the length of the season is important. In situations where viewing deer is an objective, hunting disturbances should be kept to a minimum. Thus, the required number of hunters needed to reduce the deer population should be accomodated in the shortest possible time that safety considerations will allow.

Acknowledgments. This study is a contribution of the Ohio Cooperative Wildlife Research Unit, jointly supported by the Ohio Division of Wildlife, Ohio State University, U.S. Fish and Wildlife Service, and Wildlife Management Institute.

LITERATURE CITED

Altmann, M. 1958 The flight distance in free-ranging big game. J. Wildl. Manage. 22: 207–209.

Andrews, D. A., D. D. Haugen, D. T. Palmer and G. A. Rost 1977 Annual report of USFWS wildlife management activities, Plum Brook Station (FY 1977). NASA/LRC–WMS C–73180 (10/1/76) 34 pp. Duplicated.

Behrend, D. F. and R. A. Lubeck 1968 Summer flight behavior of white-tailed deer in two Adirondack forests. J. Wildl. Manage. 32: 615–618.

Harder, J. D. and T. J. Peterle 1974 Effect of diethylstilbestrol on reproductive performance of white-tailed deer. J. Wildl. Manage. 38: 183–196.

Hediger, H. 1968 The psychology and behavior of animals in zoos and circuses. Dover Publications, Inc., New York. 166 pp.

Holsworth, W. N. 1973 Hunting efficiency and white-tailed deer density. J. Wildl. Manage. 37: 336–342.

Krefting, L. W. and A. B. Erickson 1956 Results of special deer hunts on the Mud Lake National Wildlife Refuge, Minnesota. J. Wildl. Manage. 20: 297–302.

- - -, - - - and V. E. Gunvalson 1955 Results of controlled hunts on the Tamarac National Wildlife Refuge. J. Wildl. Manage. 19: 346–352.

Kucera, E. 1976 Deer flushing distance as related to observer's mode of travel. Wildl. Soc. Bull. 4: 128–129.

Leopold, A. S. 1963 Study of wildlife problems in national parks. Trans. N. Am. Wildl. Nat. Resour. Conf. 28: 28–45.

Losch, T. A. and D. E. Samuel 1977 Unretrieved deer left by hunters: A literature review. Trans. N.E. Sec. Wildl. Soc. 33: 19–33.

Rice, W. R. and J. D. Harder 1977 Application of multiple aerial sampling to a mark-recapture census of white-tailed deer. J. Wildl. Manage. 41: 197–206.

Roseberry, J. L., D. C. Autry, W. D. Klimstra and L. A. Mehrhoff, Jr. 1969 A controlled hunt on Crab Orchard National Wildlife Refuge. J. Wildl. Manage. 33: 791–795.

Van Etten, R. C., D. F. Switzenberg and L. Eberhardt 1965 Controlled deer hunting in a square-mile enclosure. J. Wildl. Manage. 29: 59–73.

Walther, F. R. 1969 Flight behavior and avoidance of predators in Thomson's gazelle (*Gazella thomsonii* Guenther 1884). Behaviour 34: 184–221.